

## Analysis of Meteorological Drought Changes in Afghanistan Using SPI Index

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### ABSTRACT

Meteorological drought, as a natural and significant phenomenon in the field of hydrometeorology, refers to the scarcity of precipitation and moisture in a specific region. This research was conducted with the objectives of understanding the intensity and duration of weather droughts in Afghanistan, categorizing the extent of weather droughts in Afghanistan, and detecting the trend of weather droughts across the country. To investigate the droughts in Afghanistan, daily precipitation data from the Afrodite database version V1101 was utilized, which covered the statistical precipitation records during the period of 1950-2015. Using the Standardized Precipitation Index (SPI) as a measure of drought severity, duration, and frequency, the status of droughts was examined. Based on the analysis, significant trends of droughts were observed in the northern, northeastern, southwestern, and northwestern regions of Afghanistan. Furthermore, the results indicated the occurrence of three periods: wet, normal, and drought, during the study period. The climatic conditions classification during our study period demonstrated that mild moist conditions occurred repeatedly in certain regions of Afghanistan, especially in provinces such as Khost, Paktia, Logar, Kabul, eastern Ghazni, Parwan, Panjshir, Bamyán, Kunduz, southern Takhar, Balkh, Jawzjan, Faryab, Badghis, and northern Herat. On the contrary, severe droughts were more prevalent in the eastern, northeastern, central, and southern regions of Afghanistan. Additionally, mild and moderate droughts were observed in many areas.

**Key words:** Afghanistan, Aphrodite, climate change, meteorological drought, precipitation

### INTRODUCTION

Drought is one of the natural hazards that affect human life. It is a regional phenomenon that occurs due to a lack of precipitation over a specific period of time (Livada & Assimakopulos, 2007). Drought differs from other natural phenomena as it is challenging to determine its onset and end time (Komuscu, 1999). When the intensity and spatial distribution of rainfall undergo significant changes, drought can become one of the most serious threats resulting from climate change. In other words, if the temporal and spatial patterns of precipitation are altered, it affects the Earth (Serrano et al., 2010). The likelihood of drought occurrence shows an increasing trend due to global warming (Zhang et al., 2015).

In Afghanistan, people heavily rely on rain-fed agriculture and livestock farming, making them vulnerable to global warming and changes in precipitation patterns (Snetkov, 2013). Prolonged and consecutive droughts in Afghanistan have had adverse effects on groundwater and reservoirs, impacting the livelihoods of communities in arid regions of the country and leading to the spread of diseases and significant population migration (Azimi, 1395). Afghanistan experiences a semi-arid climate with significant temperature fluctuations between day and night (Flohn et al., 1969). Limited studies have been conducted on drought and its behavior in Afghanistan. Ecologically, many parts of Afghanistan have been exposed to desertification, deforestation, and severe soil erosion in recent years. Assessing and understanding drought, considering the country's heavy reliance on agricultural activities and water resource management, is of great importance (Roustaei et al., 1399). This study aimed to examine the status of weather droughts and their spatiotemporal behavior across Afghanistan, using various indices. It appears that most parts of Afghanistan have experienced severe weather droughts.

## MATERIALS AND METHODS

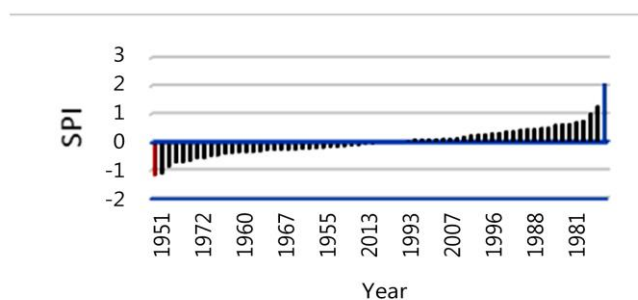
Afghanistan is a mountainous and landlocked country, located between 29 to 38 degrees north latitude and 60 to 75 degrees east longitude. This land is situated in the northern hemisphere, eastern hemisphere, and within the region of Central Asia. Its area is 659,000 square kilometers (Nami, 1387). For conducting any research, a collection of data is used that is relevant to the research objective and methodology. In this research, the Aphrodite database has been utilized. The Aphrodite database extracts daily precipitation data within the longitude range of 20 to 75 degrees east and latitude range of 15 to 55 degrees north using the 1101V version for the Middle East. In this study, the data has been used with a spatial resolution of 0.5 by 0.5 degrees. This dataset covers three separate regions, namely, seasonal Asia, the Middle East, and Russia, and provides high-resolution observational rainfall data on a daily time scale from 1950 to 2007 for assessing water resources. However, in the continuation of this research, data up to the year 2015 has been utilized. Additionally, there have been a total of 25,200 grid cells within the study area, with 248 grid cells falling within the extent of Afghanistan, out of which only 43 grid cells have available data. In fact, due to the ease of calculation and practicality, the Standardized Precipitation Index (SPI) was used from the Aphrodite database as it does not require additional variables such as evapotranspiration, temperature, or humidity. By using simple linear regression, the drought trends in Afghanistan were examined with a 95% confidence level. Additionally, the magnitude of drought reduction or increase was calculated using the non-parametric Kendall's Sen slope estimator.

## RESULTS

An analysis of the climatic conditions in Afghanistan from 1951 to 2015 based on the SPI index reveals the presence of three periods: normal, drought, and wet spells in this region. In the first period, spanning from 1951 to 1978, the climatic conditions were normal but gradually shifted towards drought. During this period, two relatively severe drought periods were observed in 1951 and 1959, along with a partial wet spell in 1976. In the second period, from 1978 to 1999, the climatic conditions remained normal and consistent. However, in the third period, from 1999 to 2015, partial wet spells were observed, with the years 2008 to 2009 experiencing more severe wet spells, and the year 2010 being considered the wettest year in this study period (Figure 1). According to the order of drought and wet spells based on the SPI index, the year 1951 has been placed as the driest year, and the year 2010 as the wettest year at the beginning and end of the graph, respectively (Figure 2).



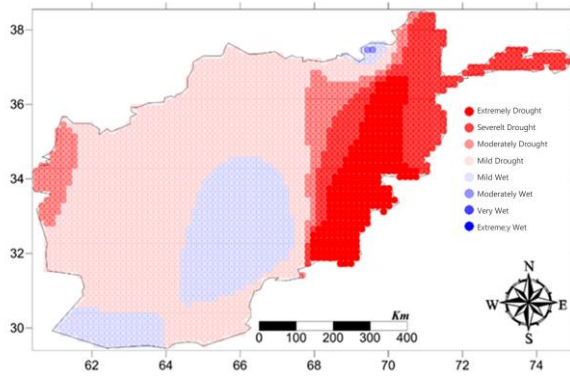
**Figure 1.** Distribution of drought and wet spells in Afghanistan during the period 1951-2015 based on the SPI index



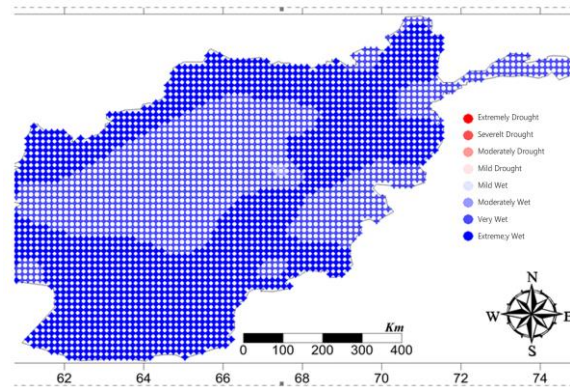
**Figure 2.** The order of drought and wet spells in Afghanistan based on the intensity during the period 1951-2015 according to the SPI index is as follows

The analysis indicates that the year 1951 is recognized as the driest year during the study period. Severe droughts have affected 10.7% of Afghanistan's territory, primarily observed in the eastern regions and parts of the northeast. Severe drought, with an impact of 11.9%, is observed in the northeastern and eastern parts of Afghanistan. Moderate droughts, covering 7.5% of the country's area, include the central, northern, and western regions. However, the prevailing conditions in this area are associated with mild droughts, accounting for 51.2% and occurring in the northern, southern, northwestern, central, and western parts of the country. Moderately humid areas, affecting 18.7% of Afghanistan's climate, are observed in the central, northern, and southwestern regions. Areas with moderate moisture conditions cover a very small area, accounting for 0.1% and located in the northern part of the country. In this year, there have been no instances of very humid or extremely humid

conditions (Figure 3). The year 2010 is recognized as the wettest year in the statistical period. In this year, 60.6% of Afghanistan's territory was under the influence of extremely humid conditions, including the southern, southeastern, parts of the eastern, northeastern, northern, northwestern, western, and southwestern regions of Afghanistan. Additionally, very humid conditions covered 39.2% of the climate in this year, including the eastern, northeastern, a small portion of the northern region, parts of the west, and the central region of Afghanistan. Furthermore, the moderately humid climate is observed in small parts of this region, accounting for 0.2% and located in the central part. In this year, due to heavy rainfall, there is no evidence of drought conditions (Figure 4).

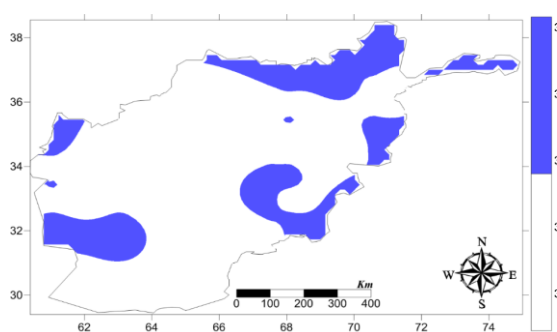


**Figure 1.** The status of Afghanistan during the most severe drought of the studied period (1951) based on the SPI index

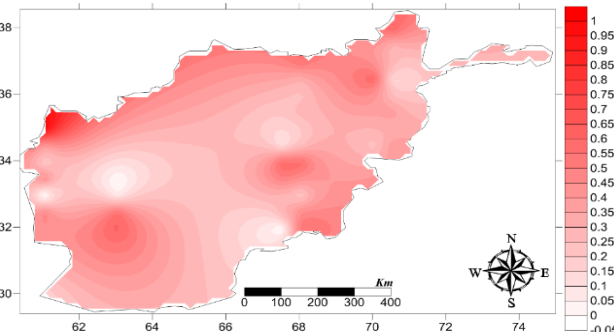


**Figure 2.** The status of Afghanistan during the wettest year of the studied period (2010) based on the SPI index

The analysis shows that in various regions of Afghanistan, using the SPI index with a 95% confidence level, droughts have exhibited a significant trend. Parts of northeastern Afghanistan, including Badakhshan province, the northern strip of Takhār, and the northern strip of Kunduz, as well as portions of northern Afghanistan, including the northern strip of Balkh and Jowzjan provinces, and parts of western Afghanistan, including the northern strip of Herat province and the southern part of Farah province, along with a section of southern Afghanistan, encompassing the northern strip of Nimruz province, and parts of eastern Afghanistan, including Khost, Paktia, Nangarhar, Kunar, and Laghman provinces, all have witnessed a notable trend in drought. Conversely, in other areas of Afghanistan, droughts have not shown a significant trend (Figure 5). Also, according to the trend of droughts in Afghanistan, based on the SPI index, it showed the decrease or increase of droughts. which is in the parts of Afghanistan which include: the northern strip of this area, the northeast of Badakhshan province, the northern strip of Herat province, the northern strip of Nimrozmi province; In the eastern part, which includes the provinces of Khost, Paktia, Kunara, and Laghman; And in the central part, which includes Ghazni province, droughts have increased. But in other parts of the country, there are no significant trends and they are observed normally (Figure 6).



**Figure 5.** The trend of Drought in Afghanistan During the Period of 1951 – 2015 based on SPI Index.



**Figure 6.** The rate of Decrease or Increase of Droughts in Afghanistan during the Period of 1951-2015 based on SPI index.

## DISCUSSION

According to the conducted research, we reach this conclusion regarding the severity and duration of meteorological droughts in Afghanistan. In the country of Afghanistan, there have been three climatic periods, including droughts, normals, and extremes in the period from 1951 to 2015. The first period is between the years (1951-1978) when the climatic conditions were normal at first and tended towards relatively severe droughts so that 1951 was introduced as the driest year, the second period is between the years (1978-1999) when the climatic conditions are normal and the same and no significant changes have occurred in the climatic conditions. However, in the third period, partial droughts have occurred between the years (1999-2015), and 2010 is introduced as the wettest year in this period. Severe droughts have occurred mostly in eastern, central and southern regions. Also, the zoning of Afghanistan in terms of meteorological droughts has occurred mostly in the northeastern, eastern, central and southern parts. And about the trend of meteorological droughts in Afghanistan, it can be said that droughts show a significant trend in the northern, central and southern parts of this country.

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